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(NSL 67-300)

ORBITING EXPERIMENT FOR STUDY OF
EXTENDED WEIGHTLESSNESS

Volume I

SUMMARY

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Prepared under Contract No. NAS1-6971 by
NORTHROP SYSTEMS LABORATORIES
Hawthorne, California
for
Langley Research Center,

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

December 1967

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SUMMARY

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ABSTRACT

This document constitutes a portion of the final report under contract NAS 1-6971, Orbiting Experiment for study of Extended Weightlessness, for the Langley Research Center, National Aeronautics and Space Administration, Hampton, Virginia. The following 6 documents comprise the total report:

NASA CR-66507	Volume I	Summary
NASA CR-66508	Volume II	System Definition
NASA CR-66509	Volume III	Spacecraft Preliminary Design
NASA CR-66510	Volume IV	Laboratory Test Model
NASA CR-66511	Volume V	Program Plans
NASA CR-66512	Volume VI	Orbiting Primate Spacecraft Applications

This report summarizes the results of a definition study of a spacecraft system to support two primates in unattended, weightless, earth-orbital flight for extended periods of time. The experiment is planned as part of the Apollo Applications Program; the spacecraft launched as a LEM substitute on an AAP flight; the primates recovered by Astronaut EVA on a later flight and returned to earth in retrieval canisters within the Command Module. Intensive post-flight examination is planned to ascertain even subtle physiological changes in the primates due to their extended exposure to weightlessness. The study includes definition of mission profile and Apollo Applications Program interfaces, preliminary design of the spacecraft, and planning for subsequent phases of the program.

Achievement of the long range goals of the nation's space programs may require that astronauts be exposed to extended periods of weightlessness. The effects of this weightless environment on man's biological processes are not yet completely known. Manned space flights to date have been of limited duration, but indicate the possibility of a number of potential effects occurring when man is exposed to prolonged periods of weightlessness. Some of these effects may only be observed as subtle changes in the body systems, yet could have significant bearing on astronaut performance or well being.

To investigate and observe these potential effects on primates as a basis for evaluating and extrapolating the effects on man, the NASA Office of Advanced Research and Technology, in conjunction with Dr. Ashton Graybiel of the Naval Aerospace Medical Institute, has proposed an "Orbiting Experiment for Study of Extended Weightlessness." Such an experiment would provide both physiological and engineering experience upon which extended flight spacecraft design can be based. The preliminary design study reported herein is an evolutionary step toward the accomplishment of the extended weightlessness experiment.

This was a preliminary design definition under Contract NASA 1-6971 to the National Aeronautics and Space Administration, Langley Research Center. The study defines a spacecraft system which would support two unrestrained primates in earth orbit for periods up to one year; would provide basic physiological and engineering data for experiment evaluation; and would provide for live retrieval of the primates at the end of the flight mission. While the study was directed toward the definition of an independent spacecraft system to perform weightlessness experiments with primates, the results of the study particularly in the subsystems evaluation and program plan areas, may have direct application to other biotechnology spacecraft programs.

The study was conducted within the Space Systems Section of Northrop Systems Laboratories, under the direction of M. O. Hesse, Program Manager. The Life Sciences efforts relating to primate physiology and behavior were directed and coordinated by Dr. R. Lindberg of the Northrop Life Sciences Section.

AiResearch Manufacturing Company, a Division of the Garrett Corporation, was employed as a consultant to Northrop in the areas of environmental control and waste management.

The cooperation of numerous Government agencies is acknowledged for providing up-to-date information. These agencies supplied information concerning Saturn/Apollo Applications Program, the Apollo spacecraft, launch vehicles, associated ground equipment, tracking and command networks, and launch facilities. Astronaut extravehicular activity and training information and primate metabolic, behavioral, and physiological characteristics were supplied as was current information on hardware development programs that could have application in this experiment.

The technical guidance and cooperation of the Langley Research Center personnel monitoring Northrop's contract effort and Mr. R. Bruce, Contract Technical Monitor, are especially acknowledged.

An index of the total documentation submitted during the contractual period, including the final report, is given in Appendix A.

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LIST OF ABBREVIATIONS

A	Analog
AAP	Apollo Applications Program
ACE	Automatic Checkout Equipment
ACM	Apollo Command Module
ACS	Attitude Control System
A/D	Analog to Digital
AFB	Air Force Base
AGC	Automatic Gain Control
Ag-Zn	Silver-Zinc
APC	Automatic Phase Control
APIC	Apollo Parts Information Center
AM	Airlock Module
ASME	American Society for Mechanical Engineers
ASPR	Armed Services Procurement Regulation
ATM	Apollo Telescope Mount
AVD	Avoidance Component
B	Biological
BCD	Binary Coded Decimal
BLO	Phase Lock Loop Bandwidth of Ground Receiver
BPM	Beats Per Minute
BW	Bandwidth
C	Control (Present)
C&C	Command and Control
CCW	Counter-Clockwise
C/D	Count Down

CDR	Critical Design Review
CEI	Contract End Item
CG	Center of Gravity
CIBA	CIBA Parmaceutical Company
C _L	Centerline
CM	Command Module
Cmds	Commands
C/O	Checkout
CO ₂	Carbon Dioxide
CONFAC	Configuration Factor Computer Program
CRB	Configuration Review Board
CSM	Command Service Module
CW	Clockwise
D	Degradation
DAF	Data Acquisition Facilities
DB	Decibel
DCASR	Defense Contract Administrative Service Region Agent
DFO	Director of Flight Operations
DMU	Dual Maneuvering Unit
DOD	Department of Defense
DR	Discrepancy Report
DRD	Document Requirement Description
DRL	Data Requirements List
DRR	Document Request and Release
DSIF	Deep Space Instrumentation Facilities
E	Engineering
E	Event

ECG	Electrocardiogram
ECP	Engineering Change Proposal
ECS	Environmental Control System
ECU	Environmental Control Unit
EDS	Experiment Data System
EKG	Electrocardiogram
EO	Engineering Order
EMI	Electromagnetic Interference
ETR	Eastern Test Range
EVA	Extravehicular Activity
EXC	Exercise Component
FAB	Fabrication
FACI	First Article Configuration Inspection
FARADA	Failure Rate Data Program
FC-75	Minnesota Mining & Manufacturing (Product Designator)
FM	Frequency Modulated
FMEA	Failure Mode, Effect, and Analysis
FMECA	Failure Mode, Effect, and Criticality Analysis
FOV	Field-of-View
FSC	Flight Spacecraft
FTM	Functional Test Model
GAEC	Grumman Aircraft Engineering Corporation
G&C	Guidance and Control
GCPY	Gas Consumed Per Year
Gen.	Generator
GETS	Ground Equipment Test Set

GFE	Government Furnished Equipment
Gnd	Ground
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
h	Unit of Hysteresis
Hg	Mercury
Hz	Hertz
ICD	Interface Control Document
I.D.	Inside Diameter
IDD	Interface Definition Document
IDEP	Interservice Data Exchange Program
ILK	Interlock Task
I/O	Input/Output
IR	Infrared
IU	Instrument Unit
KC	Kilocycles
Kg	Kilogram
KSC	Kennedy Space Center
LEM	Lunar Excursion Module
LES	Launch Escape System
LiOH	Lithium Hydroxide
LM	Lunar Module
LMS	Lunar Mapping System
LMSS	Lunar Mapping and Survey System
LOS	Line-of-Sight
LRC	Langley Research Center

LSS	Life Support System
LTM	Laboratory Test Model
LUT	Launch Umbilical Tower
LV	Launch Vehicle
M	Mission
MAA	Maintenance Assembly Area
MAAS	Manufacturing Assembly and Acceptance Sheet
MC	Control Moment
MCC-H	Mission Control Center - Houston
MCP	Management Control Plan
MDA	Multiple Docking Adapter
MEI	Master End Item
MFOD	Manned Flight Operations Division
MHz	MegaHertz
MLF	Mobile Launch Facility
M&O	Mission and Operations
MOL	Manned Orbiting Laboratory
MRB	Materials Review Board
MS	Multiple Schedule
MSC	Manned Spacecraft Center
MSF	Manned Space Flight
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
MSOB	Manned Spacecraft Operation Building
M/VM	Mass/Volume Measurement
M/V MD	Mass/Volume Measurement Device

N	Nuisance
NA	Not Applicable
NAA	North American Aviation, Inc.
NAMI	Naval Aerospace Medical Institute
NASCOM	NASA Communications Division
NASCOP	NASA Communications Operating Procedures
NRZC	Non-Return to Zero Change
NSL	Northrop Systems Laboratories
OCF	Operational Checkout Procedures
O.D.	Outside Diameter
OMSF	Office of Manned Spaceflight
OPS	Orbiting Primate Spacecraft
P	Performance (past)
PAM	Pulse Amplitude Modulation
PCM	Pulse Code Modulation
PCU	Pyrotechnic Control Unit
PDR	Preliminary Design Review
PERT	Program Evaluation Review Techniques
PI	Principal Investigation
PIA	Preinstallation Acceptance (test)
PLSS	Portable Life Support System
PM	Phase Modulation
PPM	Parts Per Million
PRINCE	Parts Reliability Information Center
PSC	Primate Spacecraft
PWR	Power
Q	Quick look

QA	Quality Assurance
QC	Quality Control
QM	Qualification Model
QTM	Qualification Test Model
R	Redundant feature
Rad	Irradiation dose unit of measurement
Rad.	Radius
RCS	Reaction Control System
RF	Radio Frequency
RH	Relative Humidity
RMS	Root Mean Square
RTG	Radioisotope Thermoelectric Generator
S	Safety
SAA	Saturn Apollo Applications
S/AAP	Saturn Apollo Applications Program
S/C	Spacecraft
SCD	Specification Control Drawing
SCN	Specification Change Notice
Seq	Sequence
SGL	Space Ground Link
SIB	Saturn IB
SLA	Spacecraft LEM Adapter
SM	Service Module
SNR	Signal to Noise Ratio
SPS	Service Propulsion System
SRO	Superintendent of Range Operations
STADAN	Space Tracking and Data Acquisition Network

INTRODUCTION AND SUMMARY

This report summarizes the results of a definition study of a spacecraft system to be designed for support of the Orbiting Experiment for Study of Extended Weightlessness. The purpose of the orbiting experiment, as stated in the Contract NASA 1-6971 Work Statement, is to study the effects of extended weightlessness on two primates while in unattended earth orbit for periods up to one year. The engineering and physiological experience derived from this study will provide guidance in the continuing research program leading to long duration manned flights.

This study resulted in the definition and preliminary design of a spacecraft which can be inserted into orbit by a Saturn IB launch vehicle within the Saturn/Apollo Applications (SAA) Program. The spacecraft subsystems are based on current state-of-art concepts and utilize existing hardware to the maximum extent possible. Interfaces between the Primate Spacecraft and related segments of the SAA Program impose no significant modification requirements on existing SAA equipment. Mission analysis, program planning and hardware selections accomplished during the study lead to the conclusion that the orbiting primate experiment can be conducted in the time frame of a late 1970 launch.

The results of this study are presented in a six volume final report. This volume (Volume I - Summary) of the report, summarizes the entire study as presented in greater detail in the five subsequent volumes.

Volume II - System Definition, defines the subsystems required for the spacecraft. Requirements of those subsystems are documented in the Master End Item (MEI) Specification for the spacecraft. The SAA Program interfaces are defined in Volume II as are the reliability concepts. The results of system level trade studies which determined selection of the major system and spacecraft configuration approaches are summarized in Volume II.

Volume III - Spacecraft Preliminary Design, describes in detail the subsystems selected and how each subsystem was integrated and synthesized into the complete spacecraft. The design is further presented in a set of spacecraft drawings and in the appropriate sections of the spacecraft MEI Specification.

Volume IV - Laboratory Test Model, describes the ground test system which duplicates the major elements of the spacecraft's life support equipment, and simulates the flight spacecraft in all aspects that physically interface with the primates except for zero gravity. The Laboratory Test Model will be used to substantiate the key subsystem approaches which have been selected for the flight spacecraft. The Laboratory Test Model will further be used to prove design adequacy, provide reliability data on subsystems, and provide a model for training of experiment primates. A set of design drawings and an MEI Specification for the Laboratory Test Model have been provided. This package of drawings and specifications constitutes the data package which further describes the Laboratory Test Model in sufficient detail to permit procurement of this portion of the Orbiting Experiment Program.

Volume V - Program Plans, outlines a 6-month Design Phase 2 and a 21-month Development/Operations Phase 3 plan for implementing the orbiting experiment. Concurrent with the initiation of the Phase 2 detail spacecraft design, a 10-month effort for detail design, fabrication, and functional test of the complete Laboratory Test Model is described. A master phasing schedule is presented in which the Orbiting Experiment Spacecraft could be inserted into orbit on SAA flight No. 218 currently programmed for launch in late 1970. A 1-year mission would permit primate retrieval by astronauts in 1971 on an SAA flight in the later 221 to 228 series. Intermediate SAA programmed launches in the 221 to 228 series would permit primate recovery after experiment missions of approximately six months and nine months duration.

Volume VI - Orbiting Primate Spacecraft Applications, describes the results of studies to determine the versatility of the spacecraft for performing additional experiments and for applications of the spacecraft to alternate mission modes. Areas examined for extended use of the spacecraft were:

- (1) Performance of additional experiments together with the prime experiment of two primates in unattended, extended duration, zero gravity earth orbit.
- (2) Performance of other biological experiments in place of the prime experiment of two primates in unattended, extended duration, zero gravity earth orbit.
- (3) Application of the primate spacecraft or its systems in connection with an orbiting laboratory.

A pictorial representation of the spacecraft is shown in figure 1. It is 10 feet high, 9 feet in diameter and will weigh approximately 5,000 pounds.

PROGRAM OBJECTIVES

There are four scientific objectives of this experiment program. These objectives are as follows:

- (1) Provide physiological and psychological data on the effects of extended weightlessness
- (2) Delineate weightlessness effects on vestibular functions
- (3) Provide scaling factors for long term life support requirements in weightless environment
- (4) Provide experience on the performance of long term life support components.

The information obtained from this experiment will provide a better understanding of effects caused by a zero gravity environment. Of particular

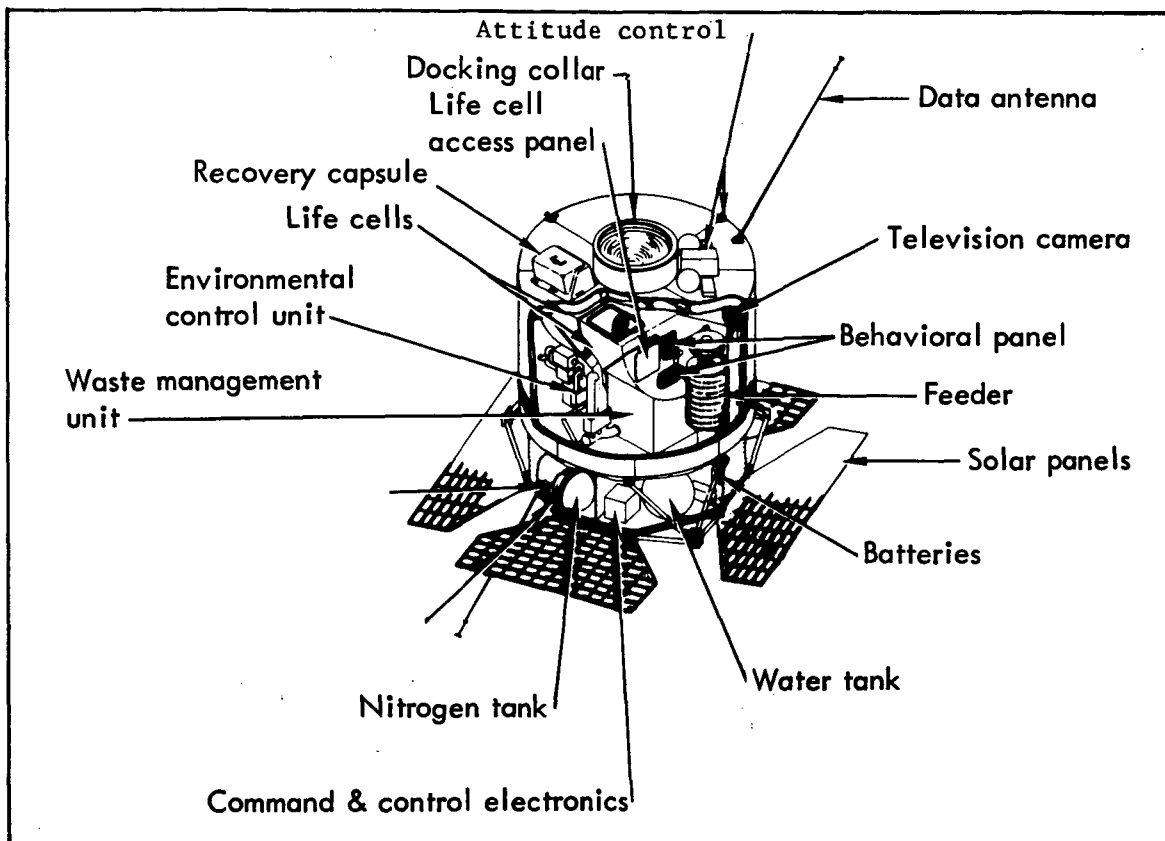


Figure 1. - Isometric view of orbiting primate spacecraft

interest will be the observation of subtle physiological changes which cannot be anticipated or postulated at this time, but might appear after a long term test.

To achieve these objectives, the experiment calls for two primates (Rhesus monkeys, *Macaca mulatta*) to be completely unrestrained during the test period of six months to one year while in a near earth orbit and a zero g environment. The test would be conducted in a two gas atmospheric environment, while continuous biological and engineering data are acquired and transmitted to the ground through the Manned Space Flight Network. The primates would be observed by television monitors. At the end of the orbital mission the two primates would be retrieved alive in independent Recovery Capsules and returned to earth in the Apollo Command Module.

This experiment is proposed as part of the Saturn/Apollo Applications Program and establishes, as a goal, a space experiment starting in the period of mid or late 1970.

STUDY OBJECTIVES AND GUIDELINES

Objectives

The principal objective of the preliminary design study was to define an Orbiting Primate Spacecraft that could support the Weightlessness Experiment. Basic to this definition is supporting analyses, preliminary spacecraft design, and preparation of specifications and drawings. The definition includes identification of system interfaces for compatibility between the spacecraft, the experiment, and the Saturn/Apollo Applications Program.

A further objective was to define a Laboratory Test Model which can be used to demonstrate the Life Support Subsystem designs and to prepare the specifications and drawings to permit procurement of the Laboratory Test Model.

Program plans for implementing the Laboratory Test Model procurement and for outlining the subsequent Phase C and Phase D programs for development of the final flight spacecraft were additional objectives of the study.

Guidelines

Specific contractual guidelines to be followed in deriving the spacecraft design are presented as requirements and constraints in the System Definition discussion and in the appropriate Subsystem discussions in the Spacecraft Preliminary Design, Volume III. Those guidelines delineate numerous detailed requirements that the various spacecraft subsystems must meet.

The more general study guidelines that were imposed on the overall system are listed below:

(1) The Orbital Spacecraft configuration should be compatible with one or more locations in the Saturn/Apollo configuration.

(2) The study should include some analysis of the initial assembly of equipment hardware into the Apollo Vehicle.

(3) The study should include consideration of the launch environment on the animal and on the spacecraft design.

(4) Use of the astronauts for spacecraft injection into orbit and for safe EVA recovery of the primates is to be included in the study.

(5) The spacecraft must be compatible with the Saturn/Apollo Applications Program.

(6) The spacecraft design should be developed around previously qualified hardware to the maximum extent possible with emphasis being placed on high reliability.

A significant Northrop derived guideline that was used in the trade study evaluations and selections of design approaches was that selections be based primarily on the following factors in the order shown:

- (1) Reliability
- (2) Performance Capability
- (3) Apollo Compatibility
- (4) Component Availability
- (5) Cost

Study Approach

The methodology used to conduct the study is illustrated in figure 2.

The requirements definition consisted of a comprehensive review and analysis of the experiment and mission requirements to the point where those requirements could be stated in detail as physical parameters to be met by various system elements and spacecraft subsystems. This definition detailed the program constraints as conditions within which the requirements must be met. The requirements, constraints and attendant prime characteristics description, mission, EVA, and telecommunications analyses, and the launch vehicle interfaces were documented in a Mission and Experiment Requirements Digest (ref. 1), which served as a compendium of detailed data for use in subsequent study activities. The experiment requirements and the mission requirements portion of the Digest constituted a comprehensive definition of the problems to be solved.

The system and subsystem engineering activities investigated the alternate approaches to solving those problems in an integrated spacecraft which would meet subsystem requirements and be compatible with other elements of the system. Evaluations and selections of optimum approaches were performed in trade-off studies which were documented as system level (ref. 2) and subsystem level (ref. 3) trade studies.

The design activity then mechanized the selected approaches in preliminary design drawings (ref. 4, 5), and descriptions of equipment and components (ref. 6) for both the flight spacecraft and a Laboratory Test Model of the spacecraft. Additional loads (ref. 7) and stress (ref. 8) analyses were performed at this point to the extent that the structural integrity of the basic spacecraft configuration was verified.

Program Planning included the preparation of functional plans which outline the necessary activities and schedules for implementing subsequent phases of this program and the preparation of specifications for the Laboratory Test Model (ref. 9) and the flight spacecraft (ref. 10). The specifications were prepared to the format of the Apollo Configuration Management Manual, NPC 500-1, and Supplement 1, for consistency with the SAA Program. The functional plans are presented in the Appendices of Volume V - Program Planning, of this report.

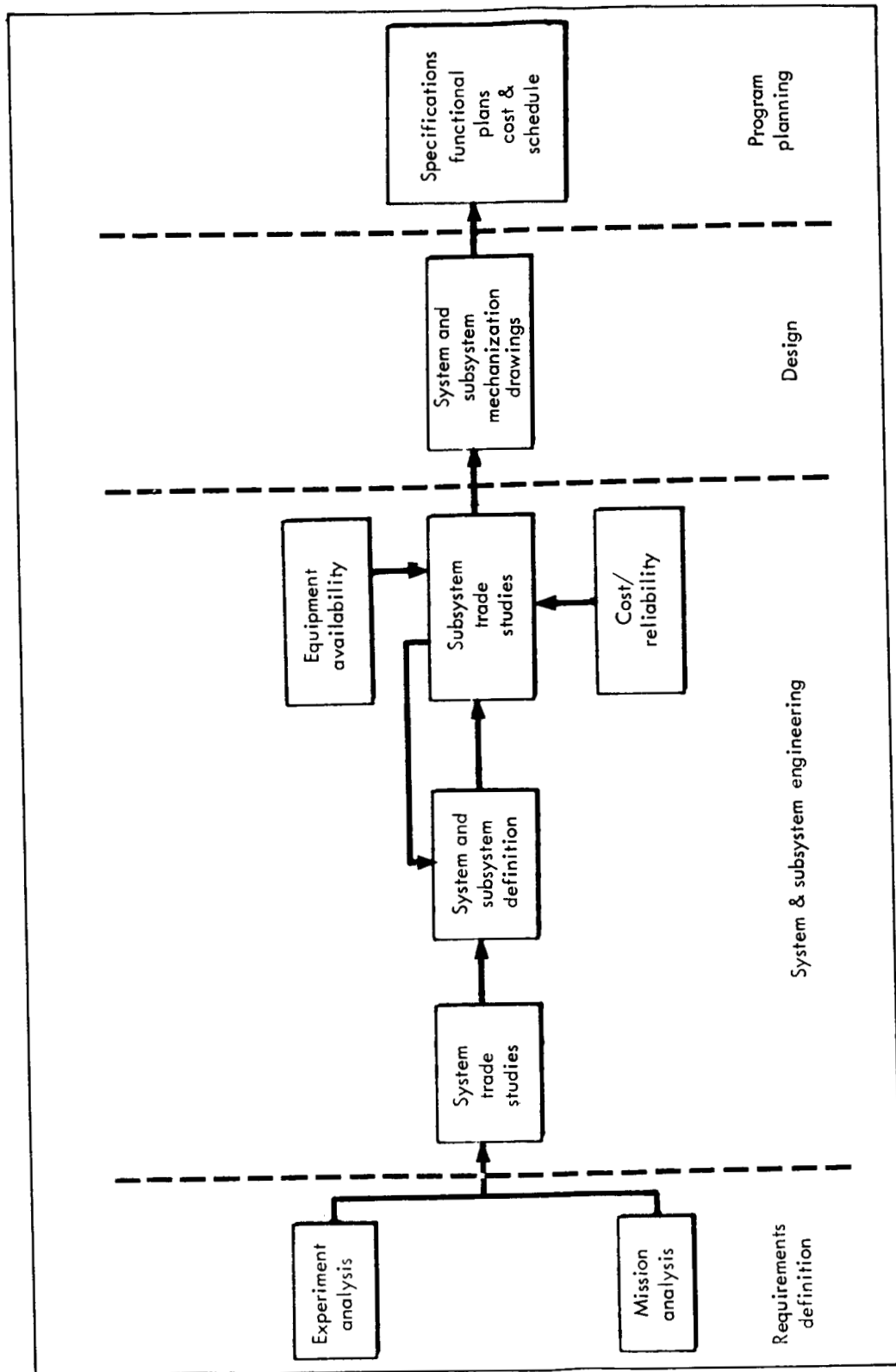


Figure 2.- Study methodology

SYSTEM DEFINITION

Requirements and Constraints

The fundamental requirements and constraints which led to the general design approaches for the Orbiting Primate Spacecraft were given as program objectives and study guidelines. More specific design criteria were derived from the primate environment, metabolic, and instrumentation requirements which must be met to sustain and analyze the experiment during the orbital period. Those requirements are summarized in tables 1 and 2. A 250 nautical mile circular orbit was selected in the mission analysis to assure an orbit lifetime capability in excess of 1 year.

TABLE 1. - SPACECRAFT DESIGN REQUIREMENTS

Item	Requirement
Duration in orbit	One year
Acceleration in orbit	Less than 0.001 g; 0.01 g transients permitted
Life cells	25 cubic feet per primate desirable
Illumination	14 hours at 25 ft-c; 10 hours at 0.01 ft-c
Noise	Less than 50 db desirable; 90 db maximum
Pressure	760 \pm 100 mm Hg (14.7 psia \pm 2 psia)
Oxygen	160 \pm 20 mm Hg (consumption: 144 lb/year/primate)
Carbon dioxide	0 to 5 mm Hg (production: 177 lb/year/primate)
Nitrogen	Balance of 760 \pm 100 mm Hg pressure
Relative humidity	60 \pm 15% with \pm 25% excursions for 2 days
Temperature	73° \pm 4° F at 50% relative humidity
Contaminants	Within human tolerance limits
Water	333 lb/year/primate
Food	120 lb/year/primate (CIBA pellets)
Waste	Remove by 30 ft/min airflow (water production: 389 lb/year/primate) (solids production: 32 lb/year/primate)

TABLE 2. - INSTRUMENTATION REQUIREMENTS

Parameter	Range	Accuracy & frequency	
Body mass	4 to 8 Kg	±1%	4 per day
Body temperature	95 to 105°F	±0.2°F	12 per hour
Electrocardiograph	-1 to +1 MV	±2%	5 min every 6 hours
Respiratory rate	20 to 60 BPM	±1 BPM	12 per hour
Activity	10,000 to 40,000 counts per day	±100 counts	Accumulate counts each minute
Sound	20 -20,000 Hz	-----	Voice key
Appearance	Close and wide angle lens	-----	1 min each daylight hour 1 min at midnight 1 min at lights on 1 min at lights out 30 sec real time over station

Saturn/Apollo Applications Program Interfaces

The Orbiting Primate Spacecraft will be launched during a Saturn/Apollo Applications mission and the animals will be recovered one year later by a second SAA mission flight without compromising either basic mission. The Orbiting Primate Spacecraft and its ground support equipment must be integrated into the SAA launch schedule and must interface with the MSOB and facilities at Launch Pads 34 or 37B at Kennedy Spaceflight Center.

During the prelaunch and launch operations, the spacecraft interfaces directly with the launch vehicle Spacecraft LEM Adapter (SLA) area as well as the ATM rack. Intense broad-band random acoustic noise levels exist within the SLA because of Saturn IB engine noise at lift-off and during transonic and maximum Q portions of flight due to aerodynamic turbulence along the SLA surface. Peak acoustic vibration levels of approximately 2 db below reference (150 db) will be experienced at the maximum Q point in the launch trajectory. Peak vibration levels at the spacecraft location within the SLA, are 0.3 G²/CPS in the 15 to 30 Hz range.

In undergoing the Hohmann transfer to 250 nautical miles, the spacecraft interfaces with the Command Module docking mechanism. Following insertion into orbit, the direct interface is with the MSFN for communication purposes.

During the animal recovery phase, the two recovery capsules interface with the Apollo astronauts and the interior of the Command Module. The interfaces are physical, thermal, and electrical in nature in order to provide stowage, a heat sink and electric power for the capsules. During atmospheric reentry, the recovery capsules and the animals will be subjected to axial acceleration levels of 9.0, vibration levels of 3.9 g rms maximum and noise levels of 117 db maximum.

Mission Profile

Analysis of the Saturn/Apollo launch capability indicated that the preferred orbit insertion mode utilizes the CSM to insert the primate spacecraft into the final orbit. No orbital plane change maneuver is required, hence the primate mission would be conducted at a nominal 28.5° orbit inclination.

The mission profile is based on an orbital insertion sequence as follows:

- (1) SIB stage of Saturn IB fires from lift-off to approximately 40 nautical miles.
- (2) SIVB stage fires from 40 nautical miles and places itself, the CSM, and Orbiting Primate Spacecraft into a 100 nautical mile parking orbit.
- (3) CSM separates from S-IVB and docks with Orbiting Primate Spacecraft.
- (4) SM engine fires and increases CSM/OPS orbital velocity.
- (5) CSM/OPS Hohmann transfer to 250 nautical miles.
- (6) SM engine fires to circularize orbital altitude at 250 nautical miles.
- (7) CSM releases Orbiting Primate Spacecraft to orbit for one year.
- (8) CSM position for CM return; CM returns to earth.

The recovery sequence is similar to the insertion sequence in regard to the booster and orbital altitudes. After CSM rendezvous with the Orbiting Primate Spacecraft, the animals are removed in their recovery capsules and stored in the CM. The Orbiting Primate Spacecraft is then deactivated and left in orbit, while the CM reenters the earth's atmosphere.

Table 3 lists the SAA flight schedule involving the Saturn IB boosters that are assigned to the program. The study indicates a first choice for performing Orbiting Primate Spacecraft orbital insertion would be Flight No. 218, while any of the flights numbered 221-228 could be used for the animal recovery mission.

TABLE 3. - TENTATIVE SATURN IB/SAA FLIGHT SCHEDULE

Mission	201-208	209	210	211	212	213	214	215	216	217	218	219	220	221-228
Mission parameters														
altitude (n.m.i.)		140	275	275	220	275	275	275			140-275			140-275
inclination (°)	28.5	29	29	29	29	29	29	29			29			1 year
duration (days)	14	28	indefinite	56	indefinite	90-135	90-135	90-135			180-225			CSM/RCM
configuration	CSM-LM	CSM-M&SS	SIVB workshop airlock module	CSM + supplies & experiment hardware	LM ascent stage + ATM assembly	CSM & APP-A experiment package	CSM	CSM	CSM & air lock module	LM/ATM	CSM plus bio lab	CSM	CSM	
flight date	1968	1968	1968	1968	1968	1969	1969	1969	1970	1970	1970	1970	1970	1971-1973
Crew	3 men on manned flights	3 men	unmanned	3 men	unmanned	3 men	3 men	3 men	3 men	unmanned	2-3 men	2-3 men	3 men	3-4 men
Rendezvous	CSM rendezvous with LM	transfer to 275mi & dock with SIVB workshop	dock with CSM from flight 209	rendezvous & dock with SIVB from flight 210	CSM from flight 211 lowers to 220mi and transfers LM-ATM to 275mi	dock with workshop stage from flight 210				rendezvous & dock with in-orbit workshop & ATM modules				rendezvous & dock with in-orbit workshop modules placed in orbit by other Saturn I & V vehicles
Earth return	yes CH	yes CH	no	yes CH	no	yes CH	yes CH	yes CH	yes CH	no	yes CH	yes CH	yes CH	yes
Objective	Apollo mission training	place M & SS in orbit	place SIVB workshop in orbit	resupply SIVB workshop & man ATM from flight 212	place LM-ATM in orbit	meteorology experiments using APP-A experiment package, long duration mission, & reuse of SIVB workshop, ATM & M & SS modules.				new solar astronomy experiments installed in reused ATM, APP B, bio lab tests.				resupply missions

The study resulted in the selection of manned Saturn IB boosters for both the insertion and recovery phases of the mission. Since the primate spacecraft is designed to the constraints of the Apollo system, the Saturn V could also be used as a launch vehicle. An Atlas Centaur could be used as an unmanned orbital insertion vehicle since it is capable of placing 8,000 to 9,000 pounds into the required orbit. In a similar manner, the Titan III launch vehicle family could be used since they have the capability of injecting 8,000 to 20,000 pounds into the required orbit.

System and Subsystem Engineering

Evaluation and selection of the approaches to meet the various requirements were performed in trade-off studies. All trade-off studies were conducted and documented following a standard format to ensure consistent and integrated evaluations. Each trade study presented the following information:

- (1) Requirements and Constraints
- (2) Alternate Approaches
- (3) Comparison of Approaches
- (4) Selected Approach

By first listing all of the requirements and constraints involved in a system or subsystem synthesis process and then analyzing the alternate approaches that could be used, a feedback loop is established between the trade study and design requirements. Then, a comparison of possibilities leads to a selected approach that not only best fits the needs of the subsystem in question, but also the system as a whole. Table 4 lists the system trade studies (ref. 2) and table 5 lists the subsystem trade studies (ref. 3) generated in the process of optimizing the overall system.

A typical example of system, subsystem, and parameter interactions is illustrated in figure 3 which indicates the ranges of total spacecraft weight as a function of mission duration.

TABLE 4. - SYSTEM TRADE STUDIES

<u>Title</u>	<u>Approach Selected</u>
Spacecraft Envelope and Mass Properties	Mount spacecraft in SLA area using ATM Rack for launch
Separation, Recovery Docking and EVA	CSM withdraws primate spacecraft from SLA; hard dock, EVA verified over IVA
Pressure Envelope	Life Cells and ECS located inside pressure shell

TABLE 4. - (concluded)

Title	Approach Selected
Power Subsystem - System Interaction	Photovoltaic/Battery
Communications	MSFN Redundant telecommunications in spacecraft
Apollo GSE (Electrical)	GSE independent of ACE
Orbital TV Monitoring	Apollo TV link
Apollo Payload Analysis (Insertion Phase)	S-IVB to 100 nautical miles - CSM from 100 - 250 nautical miles
Apollo Payload Analysis (Recovery Phase)	Delayed rendezvous and reasonable launch window

TABLE 5. - SUBSYSTEM TRADE STUDIES

Subsystem	Title
Life Support	Atmosphere Supply Atmosphere Control Humidity and Temperature Control Carbon Dioxide Control Contaminant Control ECS Thermal Management Waste Management Food Supply and Dispenser Waterer Animal Cage Recovery Capsule Recovery Capsule ECS Mass Measurement
Thermal Control	Thermal Control Subsystem
Structure and Mechanical	Structure, General Arrangement & Construction Primate Recovery Capsule Storage Orbiting Spacecraft Separation Concepts Deployment Devices (Solar Panel)

TABLE 5. - (concluded)

Subsystem	Title
Instrumentation	Television Mechanization Monkey Motion Monitor Biotelemetry Receiving Equipment Remote Versus Centralized Signal Conditioning Radiation Dosimeter Instrumentation
Telemetry	OPS Tracking Network Optimization Launch Phase Data Transmission Data Handling
Command and Control	Centralized Versus Remote Control Data Encoding
Electrical Power and Cabling	Power Subsystem
Attitude Control	Attitude Control

System Description

The configuration tree of the total integrated system resulting from the trade studies and preliminary design is shown in figure 4. The following paragraphs briefly describe the major elements that make up the system.

Spacecraft. - The spacecraft is illustrated and described under the Spacecraft Preliminary Design section of this volume.

Launch vehicle. - The Saturn IB has been selected as the Primate Spacecraft launch vehicle along with the Apollo CSM serving as the orbital injection vehicle. Figure 5 depicts the complete vehicle as it would appear just before liftoff from the launch pad. Using the SIB and SIVB stages to place the CSM and Orbiting Primate Spacecraft in a 100 nautical miles parking orbit and the CSM to raise the altitude to the final value of 250 nautical miles, approximately 8,900 pounds can be placed in orbit.

Figure 6 shows the Orbiting Primate Spacecraft in several docking configurations with the CSM. Shown are, preinjection, injection, and final recovery dock modes.

Launch facilities. - The Orbiting Primate Spacecraft will be launched from Kennedy Spaceflight Center using either the facilities to be found on Pad 37b or 34. Pad 37b is capable of launching Saturn IB's incorporating

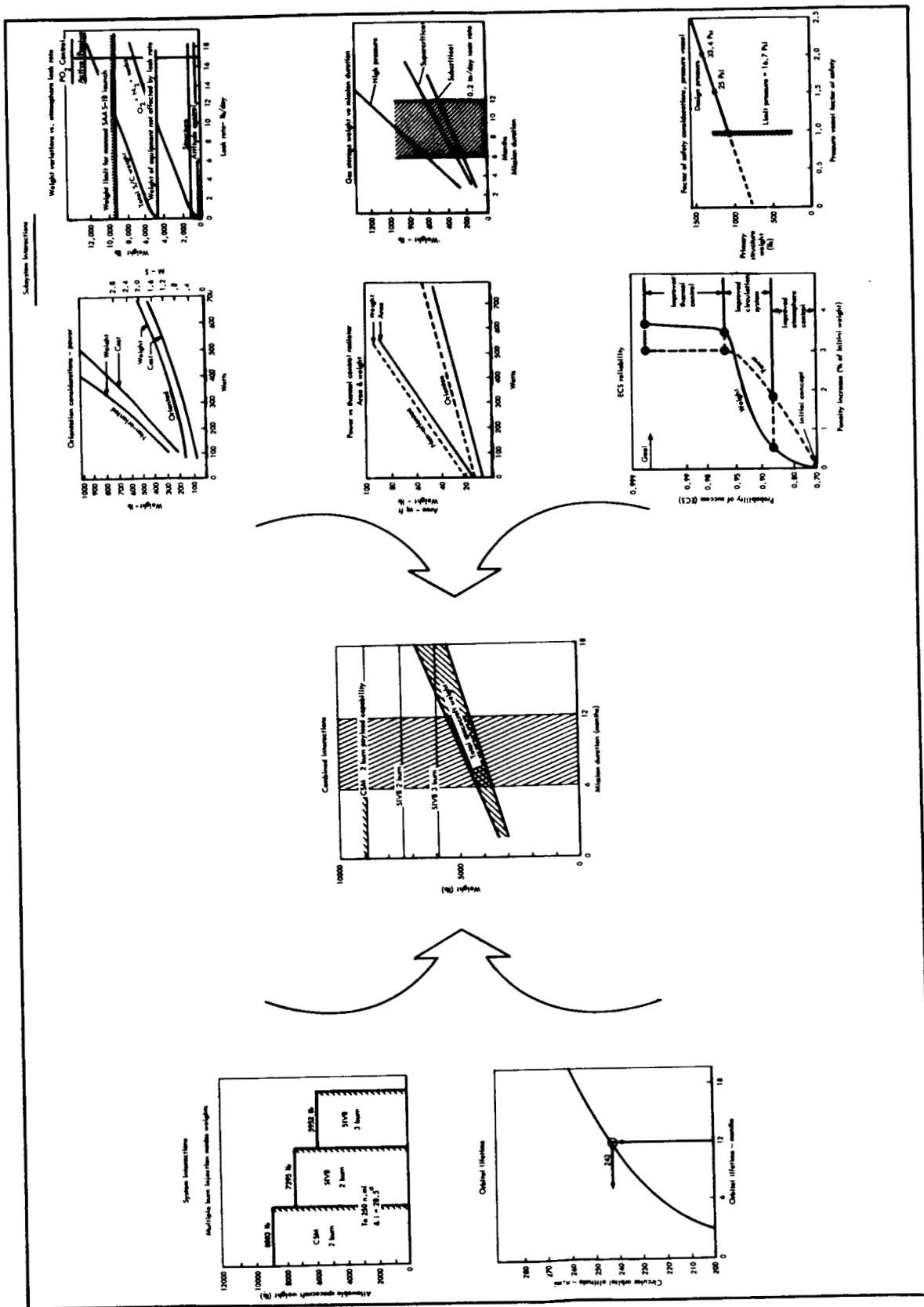
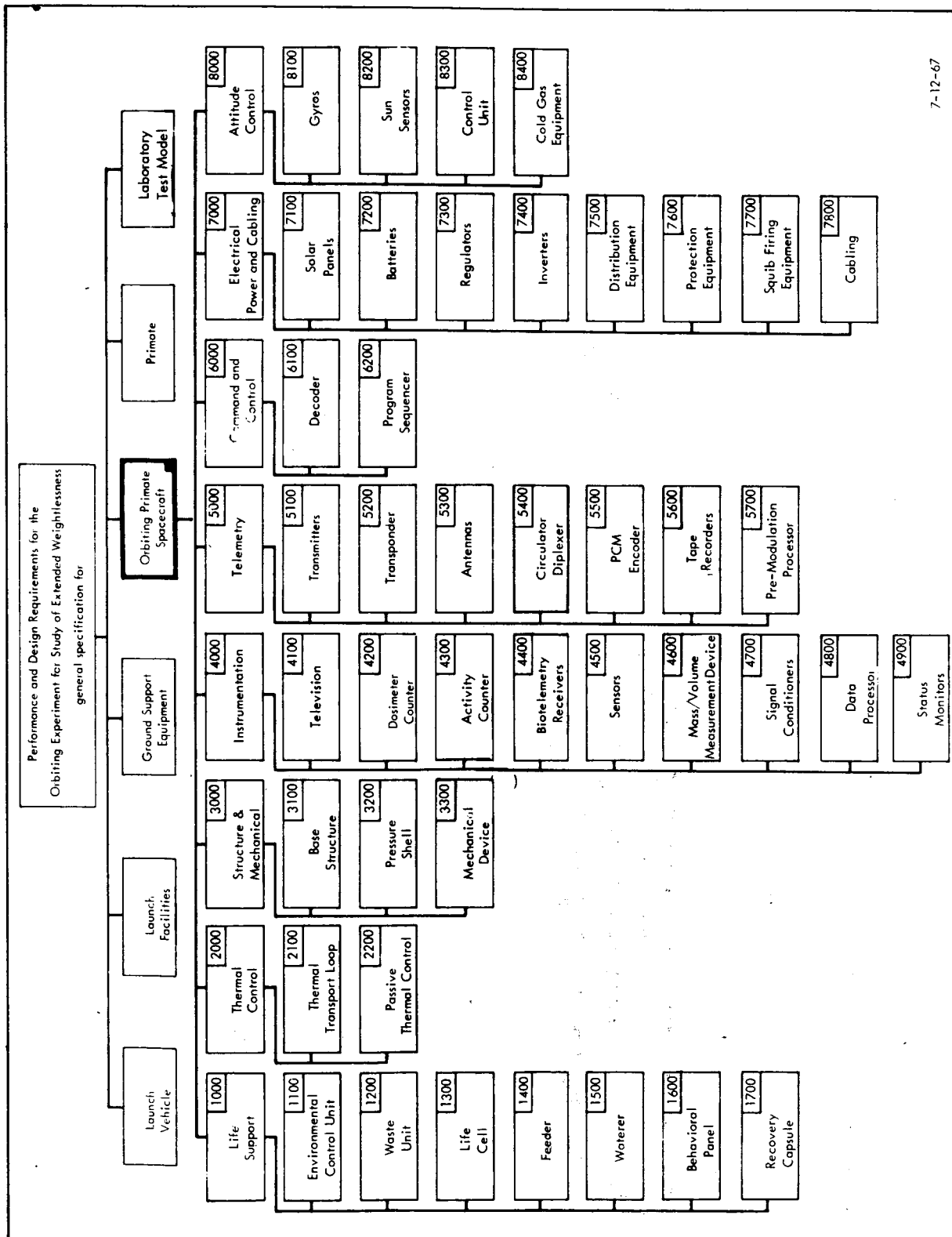


Figure 3. - Example system and subsystem interrelations: weight and mission duration



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Figure 4.- Master end item configuration tree

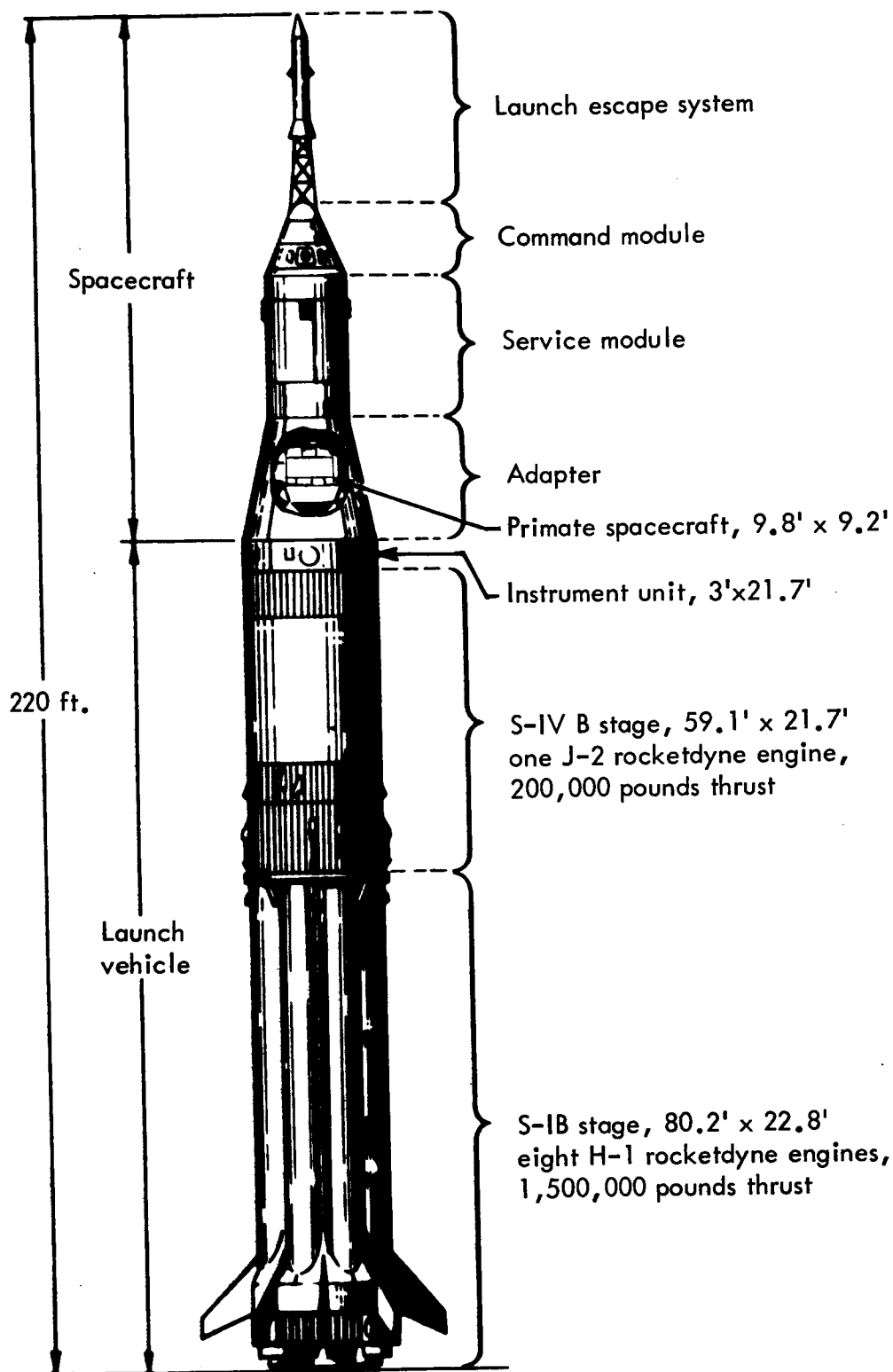


Figure 5.- OPS saturn IB launch vehicle

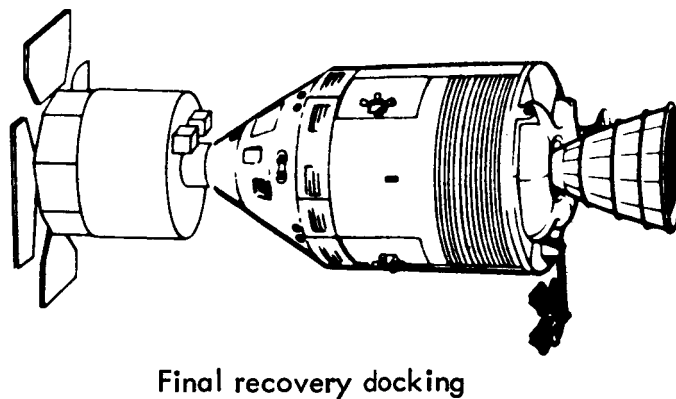
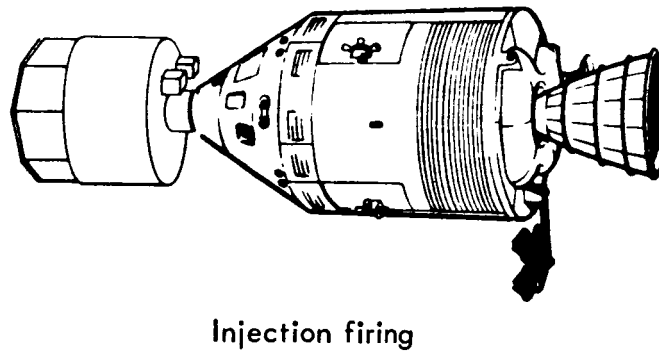
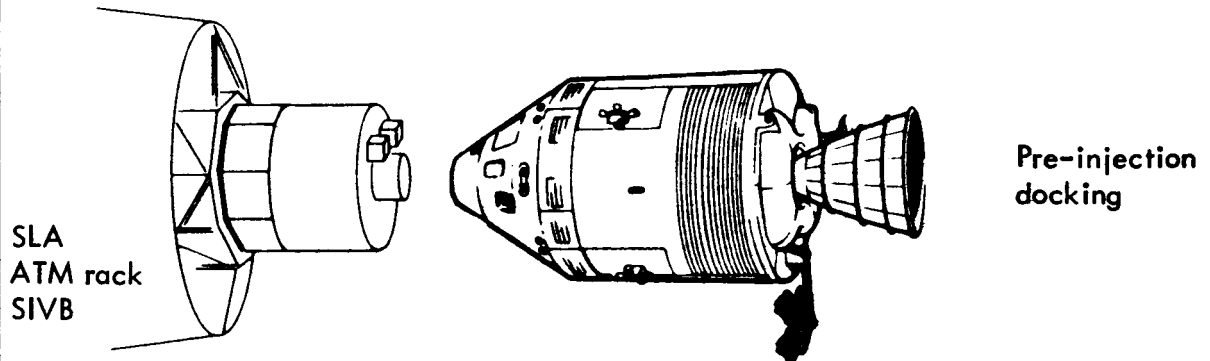


Figure 6.- CM/OPS orbital docking configurations

Apollo CSMs while Pad 34 is designed only for unmanned IB vehicles. Before the CSM and OPS are placed on the SIVB stage, they are checked out and tested in the Manned Spacecraft Operations Building (MSOB).

Ground support equipment. - Ground support equipment (GSE) required to support Orbiting Primate Spacecraft handling checkout and launch consists of electrical and mechanical hardware. Because of economic reasons and flexibility, a separate GSE system was selected over the existing Apollo Automatic Checkout Equipment (ACE). Electrical GSE will consist of one complete set of checkout equipment, the bulk of which is mounted in a single six bay console. Included will be equipment such as receivers, range code comparators, discriminators, modulators, filters, multipliers, amplifiers and crystal transmitters. AC and DC power supplies, simulated loads, power control panels and switching facilities will also be mounted in the console. Data will be recorded on stripchart and magnetic tape recorders for status evaluation.

Mechanical ground support equipment will consist of two complete sets: one for factory acceptance testing and one for launch site operation. Equipment will consist of test and work stands, transportation dollies, lifting slings and spreader beams along with protective covers. In addition, LO₂, LN₂ and GN₂ servicing equipment, coolant unit and leakage measuring devices will be supplied.

Communications. - Of the two possible communication links available for the Orbiting Primate Spacecraft Program, the MSFN and the STADAN, the MSFN was chosen because of the superior up-link command capability; superior down-link data handling capability; and the operational status during SAA flights.

Astronaut integration and participation. - Astronaut participation in the Orbiting Primate Spacecraft Program will be based on a work-load level consistent with the SAA Program. Outside of the extra vehicular activity (EVA) required to return the two recovery capsules to the CM interior, all astronaut tasks associated with placing the Orbiting Primate Spacecraft in orbit and checking out the experiment for proper operation will be conducted from within the pressurized CM. Astronaut ground training before the flights will be conducted where specific experiment tasks vary from standard Apollo procedures. The EVA required to recover the animals has been analyzed for time and metabolic requirements. An umbilical used in place of the PLSS could supply breathing atmosphere to the astronaut, since the distance from the CM hatch to the recovery capsule locations is small when the CM and OPS are hard docked. Figure 7 shows an astronaut removing a recovery capsule while still close enough to the CM hatch to be standing on its edge. Consideration of astronaut safety is made by providing a spacecraft status panel visible from the Command Module window prior to egress. This status panel provides indications of possible hazardous conditions on the spacecraft.

A study of metabolic load requirements, based on data from Gemini flights GT-9 and GT-12 was conducted. The results of the study showed that astronaut

Orbiting primate spacecraft

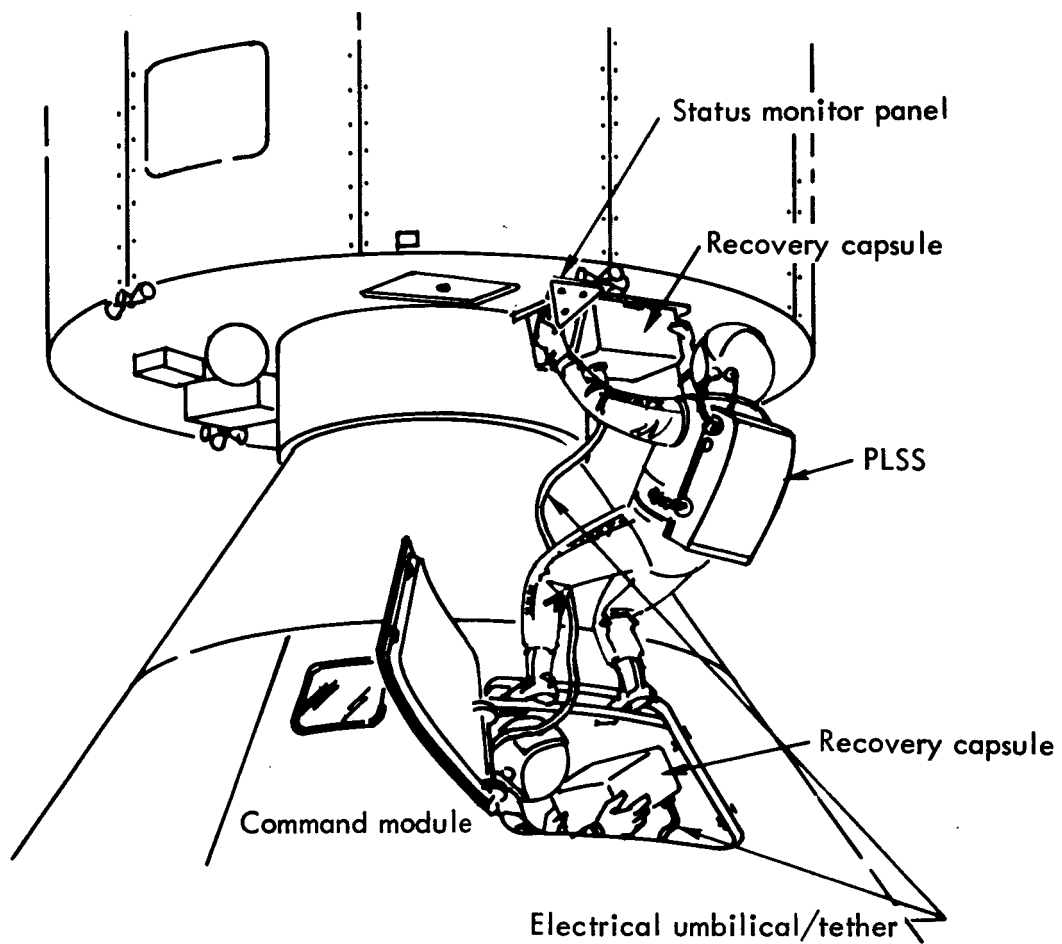


Figure 7. - EVA retrieval of recovery capsules

heat production will probably not exceed 1,500-1,600 BTU/HR. This is within the PLSS capacity to sustain a maximum continuous metabolic expenditure rate of 1,600 BTU/HR for three hours and total integrated metabolic capacity of 4,800 BTU.

Reliability Goal

A quantitative reliability goal of 0.90 for the Primate Spacecraft was established on the basis that such a goal was well within the state-of-the-art. It is obtainable using good design practices, techniques, and materials available today.

SPACECRAFT PRELIMINARY DESIGN

The design goal of the Orbiting Primate Spacecraft is to achieve an optimum balance between reliability, performance, compatibility with the SAA mission and hardware constraints and cost. Table 6 presents the estimated weights of the subsystems and spacecraft as they were evolved during these efforts. Column 1 represents the design for the nominal system. Column 2 reflects additional weight required to achieve the design of a high reliability (0.90) system. The estimated allowable payload weight for an SAA manned launch is 8,800 pounds, while for an unmanned launch this capability is 36,000 pounds.

General Configuration Arrangement

External configuration. - The external appearance of the spacecraft, shown in figure 8, is that of a cylindrical upper section joined to an octagonal lower section. The cylinder contains the pressurized volume and is of welded construction. The sides and top of the cylinder form one removable unit which is flange-mounted at a sealed joint to the bulkhead forming the bottom of the cylindrical section of the spacecraft. The lower section is unpressurized and contains most of the subsystem equipment. The flat panels forming the sides of the octagonal structure serve as bases and heat sinks for electronic equipment mounted to the interior surfaces. A sealable door is provided as access to the pressurized area for insertion of the primate or performance of maintenance. Attachments to the basic external structural stringers are meteoroid protective shielding and thermal insulation.

A radiator which is part of the Thermal Control Subsystem is mounted to the vertical stringers and covers an area of the cylindrical section approximately eleven inches in width extending completely around the circumference.

As illustrated in figure 9, four tubular truss assemblies are used to attach the spacecraft to the LMSS rack, the ATM rack, or other appropriate structures in the SLA area of the Apollo Launch Vehicle. Separation at these attach points is accomplished pyrotechnically after post-launch docking of the spacecraft and CM. Docking is accomplished through use of the docking collar located on the upper bulkhead of the spacecraft. The collar contains the LEM type drogue which engages with the CM probe during docking.

TABLE 6. - WEIGHT SUMMARY

	Nominal system	High reliability system
Life Support		
Environmental Control and Gas Storage	965 lbs.	984 lbs.
Waste Management	92	92
Life Cells	320	320
Feeders	340	340
Waterer/Storage	700	700
Recovery Capsules	105	105
Thermal Control	170	176
Structure/Mechanical	1209	1511
Instrumentation	159	159
Telemetry	204	292
Command & Control	30	30
Electric Power and Cabling	510	527
Attitude Control	<u>80</u>	<u>150</u>
TOTAL	4884 lbs.	5386 lbs.

The upper bulkhead also mounts the Attitude Control Subsystem tankage, valves, plumbing, thrusters, the gyro modules and electronic subassembly, and the primate recovery capsules which are located to facilitate removal during EVA operations. In addition, a visual docking aid for use during the docking maneuver is located on the upper bulkhead, with the spacecraft status monitoring panel which is positioned so as to be visible from the CM window.

Antennas are located on the top section of the spacecraft and consist of: five flush-mounted TV antennas (four are mounted 90° apart around the periphery and one is mounted on the top bulkhead); and a communications antenna, boom-mounted and deployable. Two more antennas are mounted at the bottom end of the spacecraft, one for TV and the other for communications. The octagonal shaped end of the spacecraft mounts the four paddles which form the solar array.

Internal configuration. - The two major internal areas of the spacecraft are the pressurized volume within the cylindrical section and the unpressurized section below it containing most of the support subsystems.

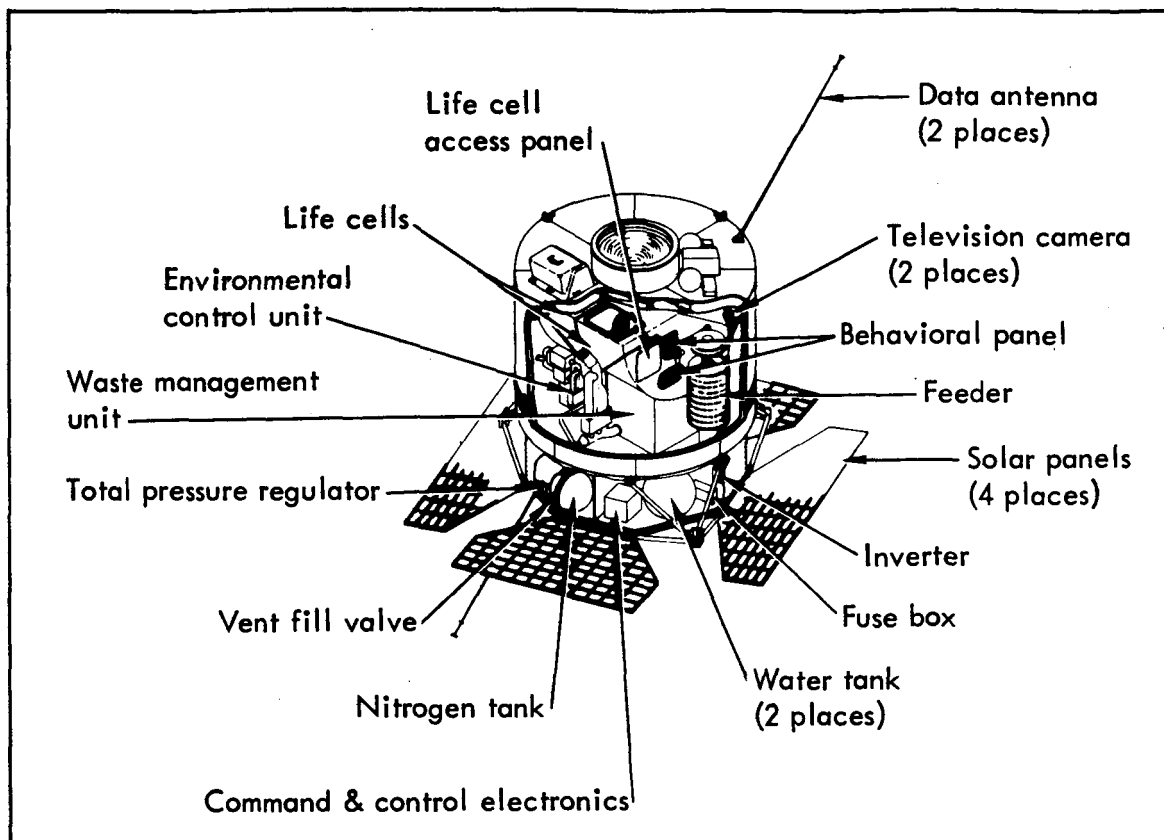


Figure 8. - Isometric view of orbiting primate spacecraft

Pressurized area: The pressurized portion of the spacecraft contains two life cells which are mounted to the bottom bulkhead. The life cells are located side by side with approximately one inch of space between to permit installation of the structural tension members. Separation between the life cell social windows precludes other than minimum physical contact between primates. The major external equipment attachments to the life cells are: television cameras, waste management assemblies at the bottom, feeders, waterers, and mass measurement devices. The recovery capsules open into the top of the life cells but are mounted externally on the upper bulkhead with a sealed transition provided to the life cell. Environmental control equipment is also mounted within the pressurized section and interfaces directly with the waste management assembly. The location of environmental control equipment was predicated upon: minimizing the number of openings for conduits, air lines, connectors, etc., from the unpressurized lower section into the pressure vessel; providing a pressurized environment for already developed hardware requiring it; and providing proximity between equipments where functional and physical interrelations so dictated.

Unpressurized area: The lower octagonal section of the spacecraft is unpressurized and contains most of the electronic subsystems elements, as well as the expendables other than the food which is stored in the feeder.

Primate spacecraft

LMSS
rack (ref)

(a) Lunar Mapping and Survey System rack

Figure 9. - Top assembly and installation OPS launch vehicle

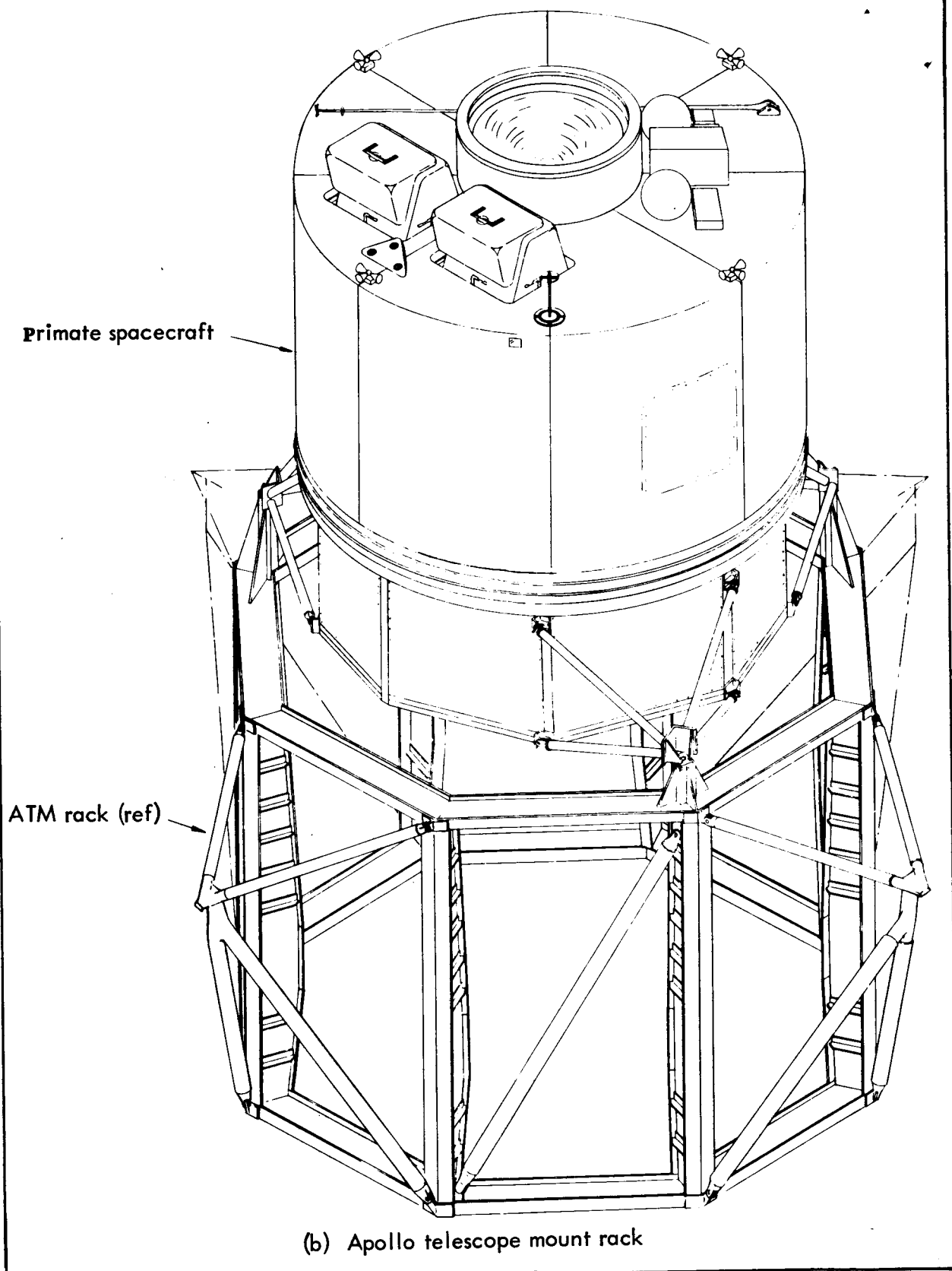


Figure 9. - Top assembly and installation OPS launch vehicle (concluded)

" The environmental control equipment located in this area consists mainly of: nitrogen and oxygen cryogenic storage tanks, heat exchanger between primary and secondary thermal loops, coolant pump, accumulator, control module, gas analyzer, and lithium hydroxide. Location of the latter unit is dictated by its need for a thermal input obtained through the surface of the spacecraft which faces the sun. The lower end of the lithium hydroxide container forms part of the bottom solar-oriented surface of the spacecraft and is centrally located there.

The environmental control expendables as well as water tankage are distributed to optimize the weight and balance during the period of consumption.

The electronic equipment is installed on: the bottom surface, the removable side panels, the central structure column formed by the lithium hydroxide container, and the bottom of the lower bulkhead of the pressure vessel.

The various equipments are segregated functionally, where feasible, with consideration given to thermal characteristics, access and maintainability. Thus, the heat dissipating elements of the power subsystem operating continuously are mounted on the flat panels forming the outside of the octagonal section. These serve as heat sinks radiating to space. Equipment which would tend to become cold is mounted on the warmer surfaces. The panels upon which equipment is mounted are designed to swing out and be removable to improve accessibility and maintainability.

Subsystems

The spacecraft subsystems have been designated as: Life Support, Thermal Control, Structure/Mechanical, Instrumentation, Telemetry, Command and Control, Electric Power and Cabling, and Attitude Control. Functional interrelationships, except for those with the Structure/Mechanical Subsystem, are shown in figure 10.

The Life Support Subsystem provides environmental control, food, water waste management, and housing during recovery for the primates.

The Thermal Control Subsystem provides temperature control for spacecraft equipment, either directly or by providing an ultimate heat sink into which the life support environmental control equipment can reject heat.

The Structural/Mechanical Subsystem provides the physical support and protection for all the spacecraft equipment and in addition supplies the necessary special mechanizations needed by the other subsystems.

The Instrumentation Subsystem consists of experiment and engineering sensors, and associated signal conditioning and processing.

The Telemetry Subsystem processes and transmits data and television from the spacecraft on 2287.5 and 2272.5 MHZ carriers respectively, and receives uplink commands from the ground on a 2106.4 MHZ carrier.

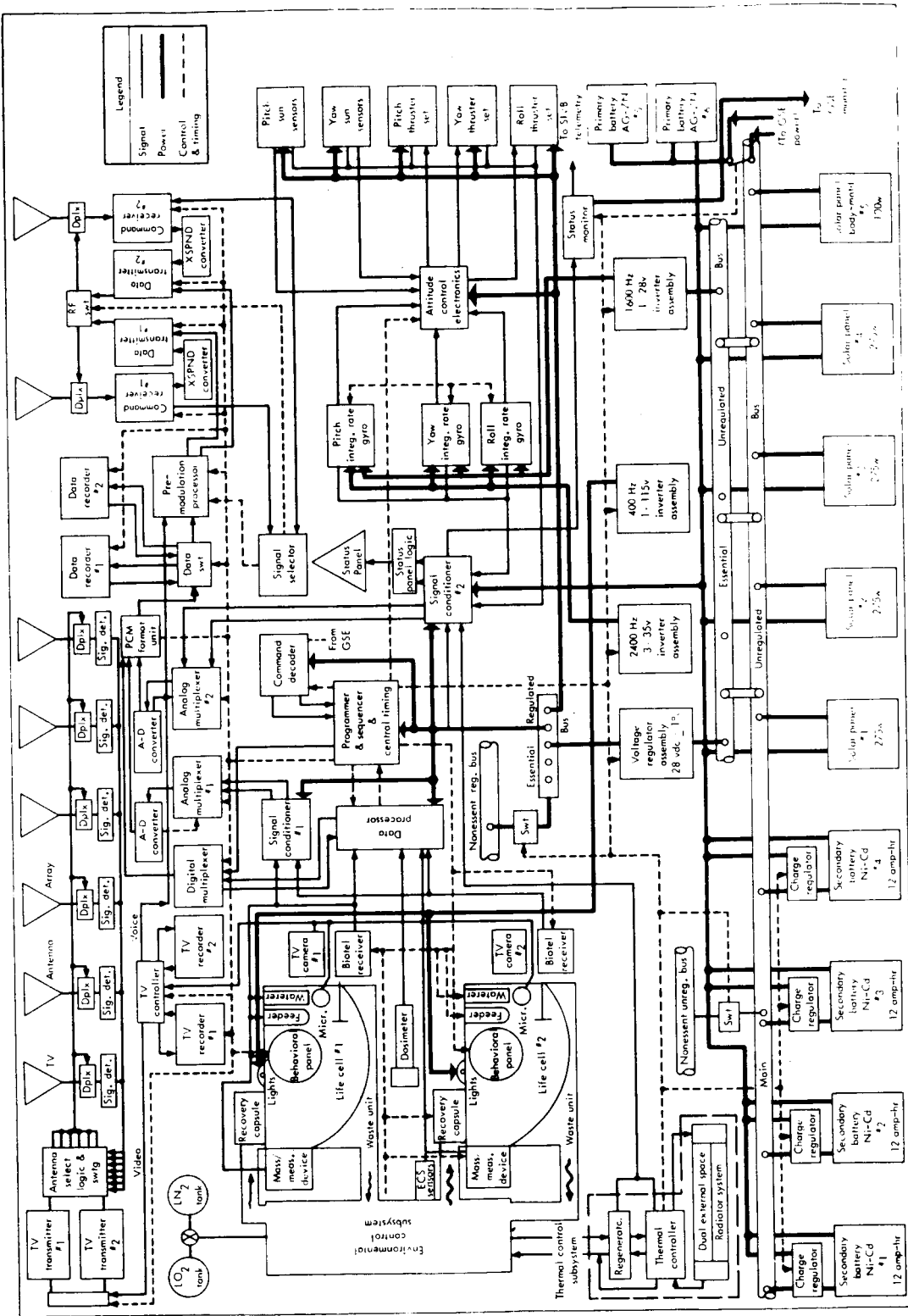


Figure 10.- Spacecraft block diagram

The Command and Control Subsystem provides preprogrammed timing and sequencing for all spacecraft subsystems which can be modified by ground commands transmitted uplink.

The Electric Power and Cabling Subsystem generates, regulates, conditions, and distributes all of the electric power required by the spacecraft subsystems.

The Attitude Control Subsystem maintains spacecraft orientation and angular rates within the prescribed limits.

LABORATORY TEST MODEL DESCRIPTION

The purpose of the Laboratory Test Model is to prove, under laboratory conditions, the design adequacy of the life support equipment proposed for use in the Orbiting Primate Spacecraft. The Laboratory Test Model will also provide accurate scaling factor data for oxygen, food and water usage, and will provide data concerning contamination control and waste management within a closed environmental control system. These data will be used in the final spacecraft designs. In addition, the Laboratory Test Model will provide a realistic training and behavioral environment for two laboratory animals. Data gathered from the animals will be used to provide an improved behavioral regimen in the space experiment and will provide baseline control data for the behavior of these animals in a closed environment such as that proposed for the Orbiting Primate Spacecraft.

General Configuration

The Laboratory Test Model consists of a pressure vessel which houses two life cells, and a control console which contains the electronics necessary for controlling and monitoring the operation of the equipment.

The pressure vessel and associated tanks, etc. contain all of the equipment that will interface with, and provide environmental support for, the primates during the one year space mission. A cut-away view of the pressure vessel is shown in figure 11.

The control console contains meters, a video tape recorder and monitor, indicators, a patch panel, power supplies, and controls used for monitoring and controlling Laboratory Test Model equipment.

Subsystems

The subsystems which comprise the Laboratory Test Model are the Life Support, Thermal Control, Structure and Mechanical, Instrumentation, and Command and Control.

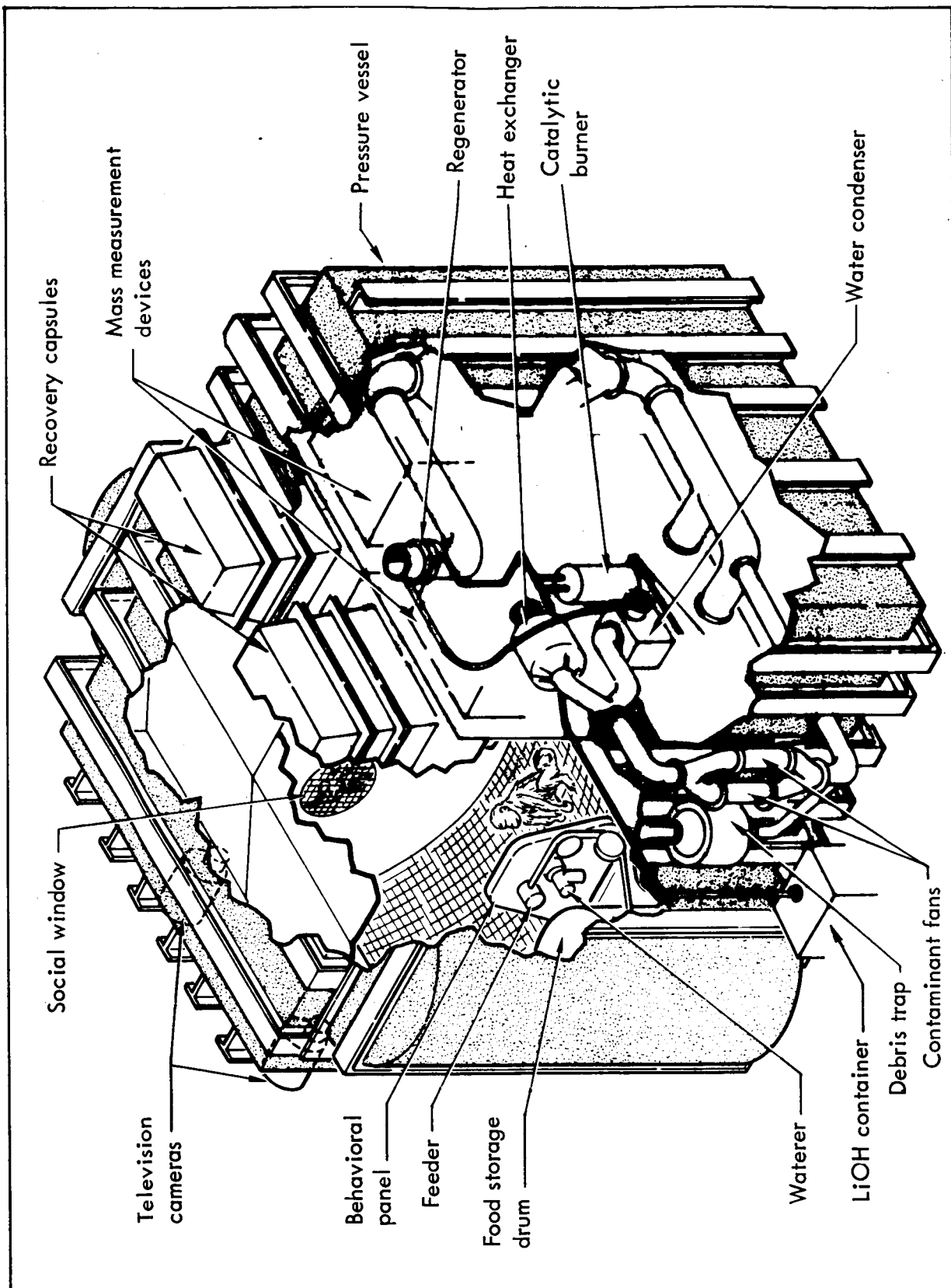


Figure 11. - Laboratory test model configuration

The Life Support Subsystem provides the vital functions required by the primate, and includes the environmental control unit, the waste unit, the life cell, the feeder, the waterer, the behavioral panel, and the recovery capsule.

The Thermal Control Subsystem provides the heat sink for the thermal outputs of the environmental control unit and for simulation of spacecraft thermal loads for enhancement of testing validity. This subsystem includes the water heat transfer unit, insulation, and the thermal simulator.

The Structure and Mechanical Subsystem provides the external support for the entire test model in the laboratory as well as the basic structure of the model itself.

The Instrumentation Subsystem provides for monitoring the primates and other operating subsystems. Included in this subsystem are the television cameras, activity counter, biotelemetry receivers, sensors, support instruments, recorders, and the mass/volume measurement device.

The Command and Control Subsystem performs a diversity of functions involving equipment control, sequencing and switching, displays, power and signal distribution. Included in this subsystem are a manual control unit, displays, power control and distribution unit and behavioral control interface unit.

PROGRAM PLANNING

The planning activity performed during the Phase 1 study is documented in Volume V and covers the program plans for detailed design, development, fabrication and delivery of a Primate Spacecraft for a late 1970 launch.

During the planning activity, three major guidelines were established as follows:

- (1) Primate Spacecraft flight readiness is required by late 1970.
- (2) A two phase follow-on program, Phase 2-Design, and Phase 3-Development/Operations, will follow the NASA standard procurement procedures.
- (3) The Laboratory Test Model Program will be related to, but separate from, the Phase C Design Program.

Schedule

The preliminary program plan for Primate Spacecraft Program is summarized in figure 12. During this two-phase effort, the Phase 2 approach will be to define in detail the requirements of the Primate Program, and to initiate the design, fabrication, checkout, and delivery of a Laboratory Test Model. The laboratory test model activity will continue into Phase 3.

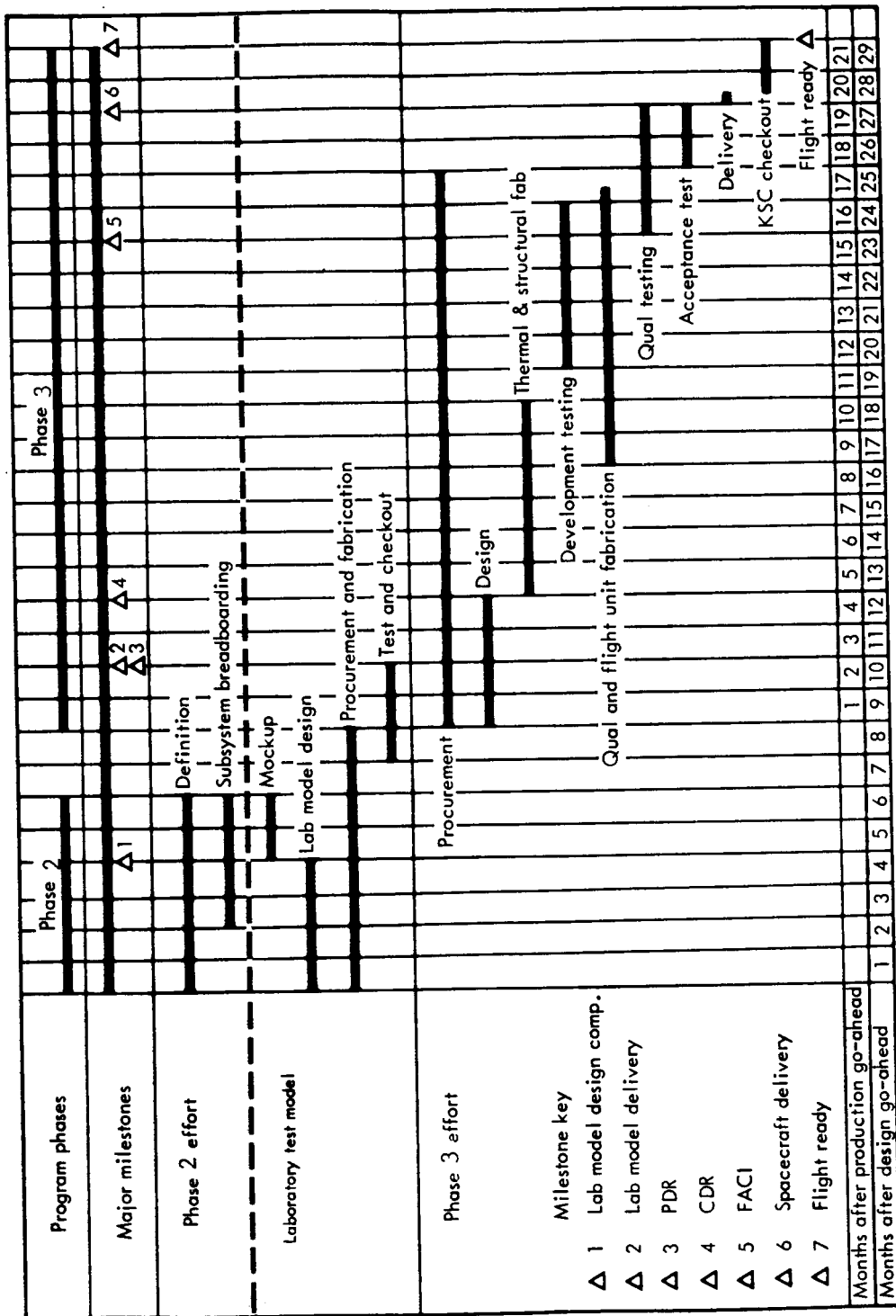


Figure 12. - Primate spacecraft program summary

Phase 3 will include detail design, fabrication, checkout, qualification, and delivery of a Primate Spacecraft to Kennedy Space Center (KSC) for a late 1970 launch. The estimated time span from Phase 2 go-ahead to spacecraft flight readiness has been established at 29 months.

Figure 12 shows major milestones of the program with the first Laboratory Test Model Design completion occurring four months after the Phase 2 go-ahead date. The Laboratory Test Model will be delivered ten months after contract award. During Phase 3, the Preliminary Design Review will be two months and Critical Design Review four months after the Phase 3 go-ahead date. First Article Configuration Inspection will occur 15 months after contract award, and the first flight spacecraft delivery will take place 19 months after award. After a two-month checkout period at KSC, the spacecraft will be flight ready 21 months from Phase 3 go-ahead date.

Plans

Volume V of this report includes seven appendices; Management Plan, Experiment Plan, Engineering Plan, Integrated Test Plan, Reliability Plan, Quality Assurance Plan and Manufacturing Plan.

Appendix A, Management Plan, describes the management techniques to be used during Phase 2 and 3 and establishes a management framework for assuring that performance, schedule and cost objectives will be achieved. This plan also identifies areas which require an advanced technology and development effort.

Appendix B, Experiment Plan, traces the experiment related tasks through all phases of spacecraft development and overall mission support operations. The gross responsibilities of the NASA, the principal investigator and Northrop, as the spacecraft contractor, are presented.

Appendix C, Engineering Plan, defines the engineering effort to be accomplished during the Design Phase and to some extent during the Development/Operations Phase. The scope of the effort described reflects the tasks to be accomplished within the major engineering organizational subdivisions.

The intent of this plan is to present an overview of the methodology, organization tasks and schedule as presently conceived for accomplishing: (1) Phase 2 detail definition of the Orbiting Primate Spacecraft, (2) design, fabrication and test of a Laboratory Test Model of the Orbiting Primate Spacecraft, (3) the development effort of Phase 3. The plan serves to delineate the responsibilities, functional interfaces, flow of information and detailed effort of the System Engineering and Design areas of the Engineering Organization.

Appendix D, Integrated Test Plan, defines the requirements for the various types of testing pertinent to the experiment, development, and operational phases of the program, and describes the rationale, schedule, criteria and

ground rules for conducting the test program. This plan also presents the interrelationships among the test programs, and establishes Northrop's comprehension of the scope and detail requirements of the program, and the physical and technical capabilities to conduct the program.

Appendix E, Reliability Plan, describes the reliability activity designed to give maximum confidence in the integrity of the spacecraft. It follows the intent and is consistent with those elements of the NASA Reliability Publication NPC 250-1 (ref. 11) considered essential to the Orbiting Primate Spacecraft Program. This document describes the objectives of the Reliability Program, the reliability concepts which will lead to their accomplishment, the reliability tasks which implement the concepts, and the selected hardware areas requiring special reliability analysis.

Appendix F, Quality Assurance Plan, describes the Quality Assurance program necessary to assure that the Orbiting Primate Spacecraft, associated Ground Support Equipment, Laboratory Test Model, and spares, meet the quality requirements of NASA programs. It describes the tasks and procedures to accomplish this objective. It follows the intent and is consistent with those elements of the NASA Quality Publication NPC 200-2 (ref. 12) considered essential to the Orbiting Primate Spacecraft Program.

Appendix G, Manufacturing Plan, describes the manufacturing planning, schedules, procurement, operations, controls, and documentation tasks which will be required of the prime contractor to fabricate and assemble the primate spacecraft. It also includes planned actions and controls relative to fabrication of mockups, breadboard electronics, test specimens and tooling.

Development Status

The majority of the spacecraft subsystems can be mechanized using state-of-the-art equipment which is developed and has been utilized in similar applications. Some equipment areas are sufficiently unique in design and application as to warrant advance development, while others although not fully developed yet have had related development done sufficient to establish concepts and feasibility. Two specific areas have been identified as requiring advance development: Mass Measurement and Waste Management. Biotelemetry (implanted sensors) and Environmental Control fall into the second grouping.

Advance development. -

Mass measurement: Measurement of mass under zero gravity conditions presents unique problems. Without the assistance of gravity, measurement of mass must rely on techniques other than weighing. The two most promising techniques employ inertia or volume measuring methods. A device for determination of mass under weightlessness conditions utilizing an inertial-oscillatory technique has been developed by Lockheed Missile and Space Company under Contract NAS 1-5999. The device was designed to determine the mass of a human subject and proved to be satisfactory if the subject was restrained in a chest harness and told to

immobilize his head, arms and legs by strong muscular tension. Similar developments have been conducted by the Air Force under Dr. W. E. Thorton of the Aerospace Medical Division, Brooks AFB, San Antonio. Reports of this activity indicate success with human subjects but poor results with animals--even well restrained dogs.

An approach to mass measurement using volumetric measuring techniques has been explored using as a basis a device developed by Acoustica Associates, Inc. of Los Angeles for measuring liquid volumes. The principle employed measures volume by means of adiabatic compression of a known atmosphere surrounding the subject in an enclosure of known volume. Northrop performed tests using this device in measuring the volumes of two *Macaca speciosa* monkeys. A problem encountered, which will require additional investigation, was attributed to animal respiration involving body dynamics of the chest cavity as they affect the pressure measurements, and thermal effects as they affect pressure measurement.

Attaining the required accuracy and providing a suitable enclosure in which to perform the measurement, and then correlating volume measurements with mass are the specific items requiring the additional development effort.

Waste management: The control and storage of wastes from an unrestrained primate in a zero g environment for a period of one year has never been attempted to date. Development of an integrated set of waste management equipment to perform the task required by the Orbiting Primate Spacecraft has been minimal to the present time. The complexities of the waste management problem are inherent in the nature of certain constituent functions of overall waste management; these are:

- Collection of waste under zero g conditions
- Storage for a one year period
- Interaction of waste storage with life cell air flow

The most promising approach to collection of waste is by means of forced air flow. The determination of air flow patterns and movement of waste in the air stream under zero g conditions will require special investigation; the findings will have a significant impact on final equipment design. The effectiveness of graded porosity filters in the zero g collection and storage of waste matter and the mechanization of their application will also require special effort. Tests conducted in the zero g portion of a parabolic flight path of a KC-135 airplane are proposed as the means to investigate these problems.

Related development. -

Implanted sensors: Implanted biotelemetry became feasible with the advent of the transistor, and research in this field has been actively pursued since early in 1959. Ames Research Center has recently directed the development of miniaturized transmitters for biotelemetry use. The results of this effort have been published in numerous NASA technical documents.

Northrop has, under contract with the NASA, successfully developed and used implanted biotelemeters for mice. During the "Perognathus as an Experimental Organism for Research in Space Biology" program, six mice were implanted with temperature-sensitive biotelemeters. Some tests were also conducted using EKG sensors. These mice have been observed during the last two years for periods of several months under various controlled environmental conditions, and data has been successfully acquired during this period. Northrop also implanted two female Rhesus monkeys with EKG and temperature sensors and associated biotelemetry. The transmitters have been successfully operating since May 1967 to date of preparation of this document (October 1967). The receiving system was similar to that proposed for the Orbiting Primate Spacecraft, i.e., three octagonal antennas, each with an independent receiver.

Environmental control, two gas atmosphere control: Investigations of oxygen partial pressure sensors for the Apollo AAP program included studies to extend the life of polarographic sensor devices, and performing life tests.

Earlier, in 1960, a two gas atmosphere control system was designed, developed, and delivered to Wright Air Development Division which controlled the composition of oxygen and nitrogen within a capsule atmosphere. Total pressure control was capable of being set at pressures of 14.7, 7.0 and 5.0 psia, which maintaining the oxygen partial pressure at 160 mm Hg.

Environmental control, brushless dc motors: In the smaller brushless dc motors that are presently being manufactured, the field is a permanent magnet and the stator serves as the armature. Some designs, such as those developed by AiResearch Corporation utilize a platinum-cobalt magnet for the field. This magnet is highly resistant to demagnetization and permits the design of an iron-less armature, which in turn permits achievement of extraordinarily high efficiencies. An example of such a motor is one which has been designed for the Apollo post-landing ventilation fan.

Environmental control, carbon dioxide removal: Considerable flight experience has been gained on Mercury and Gemini flights using lithium hydroxide (LiOH) as a CO₂ absorbent. In addition, a successful 45 day mission has recently been completed using a regenerable molecular sieve for CO₂ removal. The two-bed system operated on a 30 minute half cycle without the necessity of high temperature desorption cycles. This molecular sieve assembly will be tested at NASA, Houston, as part of the Apollo Applications Program.

Environmental control, contaminant control: Contaminant control using a catalytic burner has been studied and a development unit fabricated and tested. Methane conversion efficiency was evaluated as a function of test parameters, including catalyst poisoning, catalyst temperature, and thermal performance.

Cryogenic tankage development by AiResearch Corporation include the Gemini, Bios and MOL oxygen tanks, as well as various in-house R and D programs which exhibit thermal performance parameters approximately equal to the requirements for the primate program.

SPACECRAFT APPLICATIONS

The Orbiting Primate Spacecraft has considerable potential for extended applications. A broad spectrum of experiments ranging from engineering development testing applications to scientific experiments in the physical, planetary, and life sciences disciplines can be accepted and supported for earth orbital flights of up to one year duration.

Engineering Experiments

Studies described in Volume VI have revealed that in addition to the primate experiment, the following listed engineering experiments can be added to the spacecraft and fully supported with only relatively minor modifications to the requisite subsystems.

- (1) CO₂ concentration unit (Zeolite bed).
- (2) CO₂ reduction unit (Bosch reactor or Sabatier reactor)
- (3) Water electrolysis unit to convert water to H₂ and O₂.
- (4) Waste water recovery unit.
- (5) Ultra-violet/Infra-red Gas Analyzer unit.
- (6) Atmospheric contaminant analysis experiment.

Biological Experiments

The OPS capability for supporting two small primates for a one year mission can be employed to support smaller animal experiments for proportionately longer periods or larger animals for shorter periods. The proportional factor is dependent upon the metabolic processes of the selected experimental animals. Biological experiments studied for application to the OPS included:

- (1) Automated Primate Research Laboratory, Dr. N. Pace, Principal Investigator, University of California, Berkeley
- (2) Neurological Bio-A, W. R. Adey, M.D., Principal Investigator, University of California, Los Angeles
- (3) Reproductive Bio-A, J. P. Meehan, M.D., Principal Investigator, University of Southern California
- (4) Long Term Adaptation to a Weightless Environment, J. P. Meehan, M.D., Principal Investigator, University of Southern California

The OPS can accommodate the experiments studied but some modifications will be required. Detailed delineation of the modifications required is dependent upon further development of the desired experimental techniques.

Applications With S/AAP Orbiting Laboratory

Alternate mission modes for the OPS were studied and several attractive candidate alternatives selected. With the OPS docked to one of the radial ports of the orbital workshop Multiple Docking Adapter, the primary primate experiment or alternative biological experiments can be conducted utilizing astronaut participation to extend the scientific value of the experiments.

The OPS can be repackaged for mounting around the workshop airlock module and launched with the SIVB Workshop. Installing the primates before launch simplifies the placing of the OPS elements and does not require astronaut participation to activate the experiment. However, a launch and orbit insertion with a non-functioning experiment (no primates on board) precludes possible primate injury during an unrestrained launch. This second approach would require that the primates be brought into orbit aboard a CSM resupply vehicle and placement of the animals into their cages through a port in the airlock module wall.

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NSL 67-322	Component Description - Environmental Control and Waste Management, August 1967
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NSL 67-324	Laboratory Test Model Drawings, August 1967
NSL 67-325	Preliminary Stress Analysis, Baseline Spacecraft, July 1967
NSL 67-326	Launch Loads Baseline Spacecraft (Confidential), July 1967

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